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# Macroinvertebrate Sampling in the Upper Mississippi River System: Annual Update

#### Jennifer Sauer

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Pool 4 | Pool 8 | Pool 13
Pool 26 | Open River Reach | La Grange Pool

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# Introduction

The objective of the Long Term Resource Monitoring Program (LTRMP)

macroinvertebrate component is to annually monitor and report trends in the status and distribution of key macroinvertebrate populations. Mayflies, fingernail clams, and midges, part of the soft-sediment substrate fauna, were chosen as target organisms for the LTRMP because of their important ecological role in the UMRS. For example, Thompson (1973) found that in fall, lesser scaup (*Aythya affinis*) gizzard contents contained 76% sphaeriids and about 13% mayflies. Thompson also found the target organisms to be important to canvasbacks (*A. valisneria*), ring-necked ducks (*A. collaris*), and American coots (*Fulica americana*) feeding in open water. A number of fish, including commercial and recreational species, eat the target organisms (Hoopes 1960; Jude 1968; Ranthum 1969).

Mayflies, fingernail clams, and midges have been historically used as indicators of river water quality (Fremling 1964, 1973, 1989; Steingraber and Wiener 1995). An indicator species can be defined as a species that has particular requirements with regard to a known set of physical or chemical parameters. Macroinvertebrates also perform an important ecological function by digesting organic material and recycling nutrients (Reice and Wohlenberg 1992). Asiatic clams and zebra mussels were chosen for sampling because of their potential adverse effects on the economy and biology of the UMRS (Tucker 1995*a,b*).

The ultimate goal of the LTRMP is to improve the understanding and management of the UMRS. That goal can best be achieved by the integration of routine monitoring with experimental research directed at identifying the causes of and solutions to specific problems. Future LTRMP studies will integrate focused analyses of data from all LTRMP monitoring components (limnology, bathymetry, sediments, aquatic plants, and fisheries) with results of experimental studies to identify causes of problems and opportunities for improved management.

The present update summarizes macroinvertebrate monitoring at each of the LTRMP field stations from 2000 to the present. Tables and figures include all years of sampling for comparison purposes. Beginning in year 2000, these annual status updates are only

published online. Hard-copy reports have been published annually for the years 1992–1999. These reports are available, for a fee, in hard-copy format, from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. Electronic copies of the reports are available for the years 1993–1999 at <a href="http://www.umesc.usgs.gov/">http://www.umesc.usgs.gov/</a>

reports\_publications/ annual\_status\_reports/macro/asr\_macroinvertebrate.html.

Sauer, J. 2003. Macroinvertebrate sampling in the Upper Mississippi River System: Annual update. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. An LTRMP Web-based report available online at <a href="http://www.umesc.usgs.gov/reports\_publications/ltrmp/macro.html">http://www.umesc.usgs.gov/reports\_publications/ltrmp/macro.html</a>. (Accessed October 2003.)

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Long Term Resource Monitoring Program study reaches for macroinvertebrate sampling.

- Pool 4
- Pool 8
- Pool 13

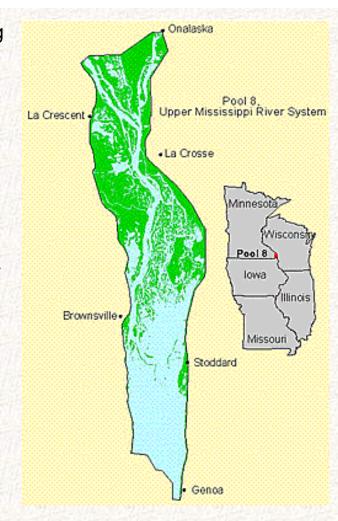
- Pool 26
- Open River Reach
- La Grange Pool

Navigation Pool 4 is 73 km (44 river miles) long and includes 14,700 ha (36,300 acres) of aquatic habitat. It is located between Lock and Dam 3 (above Red Wing, Minnesota) and Lock and Dam 4 (Alma, Wisconsin). Major tributaries include the Cannon and Vermillion Rivers on the Minnesota side and the much larger Chippewa River on the Wisconsin side. Lake

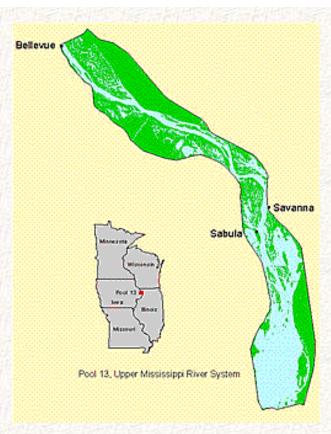


Pepin, a riverine lake created by the Chippewa River delta, is located in the middle of Pool 4. The location of Lake Pepin divides the rest of the pool into upper Pool 4 and lower Pool 4. The smaller backwaters of upper Pool 4 have been degraded by sedimentation, whereas the larger backwaters of lower Pool 4 provides much better habitat for vegetation.

**Navigation** Pool 8 is 39 km (23 river miles) long and is bounded by Lock and Dam 7 (Dresbach, Minnesota) to the north and Lock and Dam 8 (Genoa, Wisconsin) to the south. It encompasses 9,000 ha (22,100 acres) of aquatic habitat. Major tributaries include the Black, Root, and La Crosse Rivers. The upper section of Pool 8 has high bank islands adjacent to the main channel, deep secondary channels, and backwater sloughs. The middle section contains low islands, braided channels, and small backwater sloughs. The lower section is a large open expanse of water.

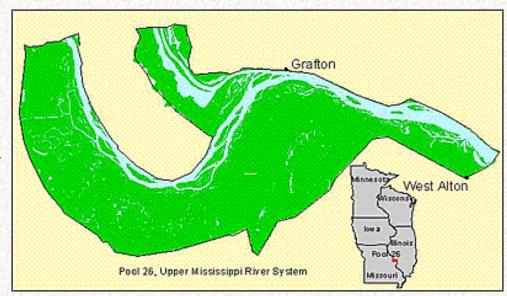


Navigation Pool 13 is 52 km (34 river miles) in length and is bounded by Lock and Dam 12 (Bellevue, Iowa) to the north and Lock and Dam 13 (Fulton, Illinois) to the south. It encompasses 11,400 ha (28,100 acres) of aquatic habitat. Similar to pools upstream, Pool 13 contains many high bank islands adjacent to the main channel in the upper section, braided backwater channels and sloughs in the middle section, and a large open lake-like area in the lower section of the pool. Major tributaries include the Apple and Plum Rivers on the Illinois side and Maquoketa and Elk Rivers on the lowa side.



## The Navigation Pool 26

study area includes water bodies along the Upper Mississippi River from Lock and Dam 25 (Winfield, Missouri) to Lock and Dam 26 (Alton, Illinois)–63 km (39 river miles) long—and the lower Illinois River from its confluence with the Mississippi River north to Illinois River mile 12. This reach of the two rivers is



bordered by high bluffs on the Illinois side and low elevation floodplain on the Missouri side. The reach encompasses 9,500 ha (23,700 acres) of aquatic habitat. Presently, most of the backwaters of the lower Illinois River are isolated from the river by low levees so as to decrease sedimentation and allow management for waterfowl. Likewise, many of the secondary channels of the Mississippi River are isolated from the river on

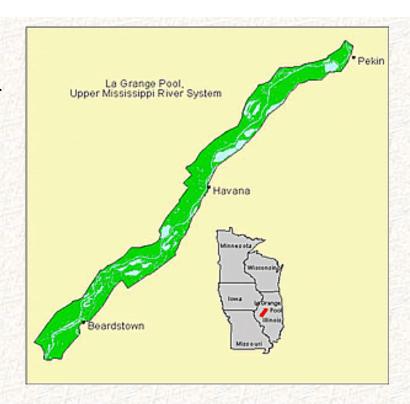
the upstream side to create backwaters and to reduce sedimentation.

The Open River Reach is 84 km (52 river miles) long. The study reach has approximately 7,241 ha (17,893 acres) of aquatic habitat in the form of open water, sand and mud flats, and swamps and marsh. The floodplain is extensively disconnected from the mainstem river by levees. Many of the islands are now joined to the mainland and most side channels contain closing structures and become disconnected from the mainstem at moderately low flows. This river reach is characterized by turbid water, high water velocities, and sand substrate; thus, the aquatic communities are dominated by more obligate riverine species than the pooled portion of the Upper Mississippi River. Major tributaries to the Open River Reach are the Little River Diversion Channel in Missouri and the Big Muddy Rivers and Cache River Diversion Channel in Illinois.



La Grange Pool on the Illinois River is about 130 km (80 river miles) long and encompasses 10,750 ha (26,500 acres) of aquatic habitat. It is bounded by Peoria Lock and Dam to the north and La Grange Lock and Dam to the south. This reach has the highest proportion of backwaters, except for Pool 4, but these backwaters are highly degraded by excessive sedimentation over the last 150 years. Many backwaters are isolated by low

levees to enhance waterfowl habitat management. Major tributaries include the Sangmon, Mackinaw, and LaMoine Rivers.



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## **Methods**

Macroinvertebrate sampling procedures are described in detail in the LTRMP Procedures Manual (Thiel and Sauer 1999). The sampling of mayflies (Ephemeridae), fingernail clams (Sphaeriidae), and Asiatic clams (*Corbicula* sp.) began in 1992 in Pools 4, 8, 13, and 26, the Open River Reach of the Mississippi River, and La Grange Pool of the Illinois River (Figure 1). Midges (Chironomidae) were added to the sampling design in 1993 and the exotic zebra mussel (*Dreissena polymorpha*) in 1995. The presence or absence of Odonata, Plecoptera, Trichoptera, Diptera, Bivalvia, Oligochaeta, Decapoda, Amphipoda, and Gastropoda was also reported.

Sites included randomly selected locations distributed among key aquatic strata—based on enduring geomorphic features (Wilcox 1993). Aquatic strata sampled included contiguous backwaters, which have apparent surface water connection with the rest of the river; main channel borders, the area between the navigational buoys and the riverbank—not including revetments and channel-training structures; impounded areas, large, mostly open-water areas located in the downstream portion of the navigation pools; and side channels, channels that carry less flow than the navigation channel. For Pool 4, the impounded area is in the form of Lake Pepin, a tributary delta lake formed by the Chippewa River delta. In this report, only data from the randomly selected sites are discussed. The LTRMP staff developed a spatial database of aquatic areas (Owens and Ruhser 1996) on the basis of aerial photography produced in 1989. This database was used for randomized selection of sampling sites and the quantification of sampling strata.

Annual sampling was conducted at about 120 sites per study area (<u>Table 1</u>). Sample allocation was based on several criteria, including surface area of the aquatic area in each study reach, ability to sample within a specific strata, and the productivity of the taxa in each aquatic area. All sites were sampled in early spring, before emergence of mayflies and much growth of vegetation occurs.

Benthic samples were collected with a winch-mounted 23- × 23-cm (0.052-m²) standard Ponar grab sampler (Ponar Grab Dredge, Wildlife Supply Company, Saginaw, Michigan). The wash frame sieve size was changed from a U.S. Standard Sieve no. 30

(0.595 mm), used in 1992, to a U.S. Standard Sieve no. 16 (1.18 mm) in 1993. Samples washed through the 1.18-mm mesh retain only the larger taxa and life stages of the invertebrate community (Dukerschein et al. 1996). Mayflies, fingernail clams, midges (>1 cm), Asiatic clams, and zebra mussels were removed from each sample and counted.

#### Site Information

Field crews qualitatively categorized the substrate and vegetation at each sampling site. They classified substrate composition in the Ponar samples into one of six categories: hard clay, silt clay with sand, sand with silt clay, sand, and gravel rock. They recorded the percentage of submersed and floating-leaved aquatic vegetation in the column of water through which the Ponar dredge fell. Also, the crews recorded the type and percent cover of vegetation and open water within a 15-m radius from the boat. Water depth was also measured at each site.

#### Statistical Analyses

Total catch was recorded for each target taxa from individual Ponar samples.

The reachwide estimated mean densities of taxa was based on by pooling data over all strata selected for macroinvertebrate sampling (Sauer 1998). These estimates track relative densities at the broadest possible spatial scale and can be used to evaluate areawide trends in abundance. If the quantity of preferred habitats declines through time while densities in those preferred habitats remains constant, these pooled mean density statistics should reflect that decline.

The estimates of pooled reachwide mean densities were obtained from the conventional design-based estimator for stratified random samples (Cochran 1977). The estimated reachwide mean, denoted  $\overline{y_{\rm st}}$  (st for stratified) is given by

$$\overline{y_{st}} = \frac{1}{N} \sum_{h=1}^{L} N_h \overline{y_h}$$

where  $N_h$  is the number of sampling units within stratum h, L is the total number of strata,  $N = \sum_{k=1}^L N_k \quad \text{and} \quad \overline{y_k} \quad \text{denotes the estimator of the sample mean}$ 

of y for stratum h. The estimator of the variance of  $\overline{y_{st}}$  is

$$s^{2}(\overline{y_{st}}) = \frac{1}{N^{2}} \sum_{h=1}^{L} N_{h}(N_{h} - n_{h}) \left(\frac{s_{h}^{2}}{n_{h}}\right)$$
 where

$$s_h^2 = \frac{\sum_{i=1}^{n_h} (y_{hi} - \bar{y}_h)^2}{n_h - 1}$$
 (2)

is the estimator of the variance of  $y_h$  and  $n_h$  is the number of samples taken in stratum h

(Cochran 1977). The standard error of 
$$\overline{y_{st}}$$
 is therefore  $s(\overline{y_{st}})$ 

Equation (1) is used to obtain estimates of overall mean densities for stratified random sampling. In random samples, equation (1) yields unbiased estimates of the reachwide means regardless of the probability distribution of y (Cochran 1977). For LTRMP macroinvertebrate monitoring, the sampling units are the 50-m<sup>2</sup> sampling grids.

# Annual Changes in Methods

**Year 1993:** The wash frame sieve size was changed from a U.S. Standard Sieve no. 30

(0.595 mm) to a U.S. Standard Sieve no. 16 (1.18 mm). Midges (Chironomidae) were added to the sampling design.

**Year 1995:** The zebra mussel (*Dreissena polymorpha*) was added to the sampling design.

**Year 2001:** The Open River Reach was dropped from the macroinvertebrate monitoring

design in 2001 because past data had documented low densities of mayflies (*Hexagenia* sp.) and fingernail clams (Sphaeriidae) and unfavorable habitat for these taxa.

Year 2002: We initiated electronic data entry in the field.

**Year 2003:** Because of budget constraints, Pools 4 and 26 of the Upper Mississippi River,

and La Grange Pool of the Illinois River were not sampled.

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where  $N_h$  is the number of sampling units within stratum h, L is the total number of strata,  $N = \sum_{k=1}^{L} N_k$  and  $\overline{y_k}$  denotes the estimator of the sample mean of y for stratum h. The estimator of the variance of  $\overline{y_{st}}$  is

$$s^{2}(\overline{y_{st}}) = \frac{1}{N^{2}} \sum_{h=1}^{L} N_{h}(N_{h} - n_{h}) \left(\frac{s_{h}^{2}}{n_{h}}\right)$$
 where

$$s_h^2 = \frac{\sum_{i=1}^{n_h} (y_{hi} - \bar{y}_h)^2}{n_h - 1}$$
 (2)

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**Table 1.** Number of random sample sites for macroinvertebrates by study reach and aquatic strata.

Study reach	Year	Backwater contiguous	Impounded <sup>a</sup>	Side channel	Main channel border	Total
Pool 4	1992	49 <sup>b</sup>	24	24	25	122
	1993	57	44	10	10	121
	1994	60	45	10	10	125
	1995	56	44	10	11	121
	1996	50	44	17	10	121
	1997	55	44	11	11	121
	1998	57	44	11	9	121
	1999	55	44	10	11	120
	2000	56	44	11	9	120
	2001	57	44	10	8	119
	2002	57	44	10	10	121
	2003 <sup>c</sup>	_	_	_	_	_

<sup>&</sup>lt;sup>a</sup>Impounded area for Pool 4 is Lake Pepin, a Tributary Delta Lake.

					Main	
		Backwater		Side	channel	
Study reach	Year	contiguous	Impounded	channel	border	Total

Contains backwater contiguous and contiguous floodplain shallow aquatic areas.

Sampling not conducted in 2003 because of budget constraints.

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Pool 8	1992	47	14	23	25	109
	1993	29	52	18	10	109
	1994	32	49	19	12	112
	1995	31	49	19	10	109
	1996	31	49	19	10	109
	1997	34	49	19	10	112
	1998	34	47	18	10	109
	1999	31	49	19	10	109
	2000	31	48	18	10	107
	2001	31	49	19	9	108
	2002	31	49	19	10	109
	2003	31	49	19	10	109

Study reach	Year	Backwater contiguous	Impounded	Side channel	Main channel border	Total
Pool 13	1992	48	24	21	25	118
	1993	43	47	14	15	119
	1994	48	47	15	15	125
	1995	44	45	11	15	115
	1996	43	47	13	15	118
	1997	43	46	14	15	118
	1998	43	46	14	15	118
	1999	43	46	14	15	118
	2000	42	47	14	15	118
	2001	43	46	13	15	117
	2002	43	46	14	15	118
	2003	43	45	14	15	117

Study reach	Year	Backwater contiguous	Impounded	Side channel	Main channel border	Total
Pool 26	1992	30	31	29	27	117
	1993	32	27	4	3	66
	1994	40	27	38	19	124
	1995 <sup>a</sup>	39	27	1	_	67
	1996	37	25	32	18	112
	1997	12	30	30	15	87
	1998	12	12	31	17	72
	1999	40	27	33	17	117
	2000	40	28	34	16	118
	2001	35	27	35	18	115
	2002	28	27	34	15	104
	2003 <sup>b</sup>	_		_	_	_

<sup>&</sup>lt;sup>a</sup>Sampling not completed because of high water.

Study reach	Year	Side channel	Main channel border	Total
Open River Reach	1992	46	46	92
	1993 <sup>a</sup>	_	_	_
	1994	49	35	84
	1995	71	42	113
	1996	69	38	107
	1997 <sup>a</sup>	_	_	_
	1998	65	43	108
	1999	65	43	108
	2000	52	45	97
	2001 <sup>b</sup>	_	<u>—</u>	_

Sampling not conducted in 2003 because of budget constraints.

<sup>a</sup>Sampling not conducted in 1993 or 1997 because of high water.

Sampling discontinued in 2001.

Study reach	Year	Backwater contiguous	Side channel	Main channel border	Total
La Grange Pool	1992	23	38	41	102
	1993	25	35	38	98
	1994	41	42	41	124
	1995	24	35	38	97
	1996	33	33	32	98
	1997	24	35	40	99
	1998	24	34	41	99
	1999	24	35	39	98
	2000	26	32	41	99
	2001	25	33	40	98
	2002	24	35	40	99
	2003 <sup>a</sup>	_	_	_	_

<sup>a</sup>Sampling not conducted in 2003 because of budget constraints.

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# **Yearly Summaries**

- Because of budget constraints, Pools 4 and 26 of the Upper Mississippi River and La Grange Pool of the Illinois River were not sampled in 2003.
- Pools 8 and 13 were selected for continued monitoring to provide data for modeling efforts that began in 2000 using data from these two pools. Also, there was a poolwide water level drawdown in Pool 8 in 2001 and 2002. The drawdown was implemented to increase vegetation abundance, which will in turn provide habitat for waterfowl and other aquatic life forms. Because this type of hydrologic change could have an effect on macroinvertebrate densities, we decided to continue the long-term data string in Pool 8.
- The poolwide estimated mean densities of mayflies, fingernail clams, and midges were all within the range of variation previously observed in Pools 8 and 13 (<u>Table 2</u>; <u>Figures 2–4</u>). The only substantial change from 2002 was in Pool 13 where mayfly densities dropped from a 12-year high of 221 to 77 m<sup>-2</sup> in 2003, which matched the 12-year low observed in 2001 (<u>Figure 2</u>).
- There was an extensive die-off in <u>zebra mussels</u> in Pools 8 and 13 (<u>Table 2</u>) in 2003 (<u>Figure 5</u>). Large numbers of dead zebra mussels were found in the samples. The few live zebra mussels found were small (<1 cm). Although the die-off was extensive, over the summer there were reports of small zebra mussels on aquatic vegetation, boats, and docks; thus, 2003 may have been a good year for recruitment. The die-off may be part of a demographic shift. Zebra mussels only live 4–5 years and our data from 1999 and 2000 indicate that large year classes of zebra mussels were produced in these pools 4–5 years ago. Thus, this may have been a natural die-off of older zebra mussels. Other potential causes include parasites, water flows, or water temperature changes in fall and winter 2002.
- The distribution of invertebrates among aquatic areas within Pools 8 and 13 was similar to previous years. The highest densities of mayflies occurred in contiguous

backwaters and impounded areas (<u>Table 3</u>), fingernail clams were most abundant in the impounded areas (<u>Table 4</u>), and midges in the contiguous backwaters (<u>Table 5</u>).

- Overall, the high spring flood of 2001 did not seem to have an adverse effect on macroinvertebrate numbers in 2002. In fact, several aquatic areas in Pool 26 and La Grange Pool study areas recorded the highest densities of fingernail clams and midges seen since sampling began in 1992 (see below).
- Macroinvertebrate sampling in 2002 produced a total of 2,411 mayflies, 3,983 fingernail clams, 3,514 midges, 1 Asiatic clam, and 3,700 zebra mussels from 551 total samples. This is a 50% increase in the total number of mayflies, 21% increase in the total number of fingernail clams, and a 98% increase in midges from 2001, yet these numbers are still within the range of numbers seen since sampling began in 1992. The total number of zebra mussels collected in 2002, decreased 53% from 2001.
- The poolwide estimated mean densities of mayflies decreased between 2001 and 2002 in Pools 4 and 8, while Pools 13 and 26 and La Grange Pool showed increases (<u>Table 2</u>; <u>Figures 2-4</u>). All study areas, except for Pool 4, had increases in the poolwide estimated mean densities of fingernail clams and midges. Pool 13 was the only study area that had increases in all of the target taxa.
- In Pool 13, the poolwide estimated mean densities of midges dropped precipitously from 574 m<sup>-2</sup> in 2000 (the highest level ever recorded by LTRMP) to 28 m<sup>-2</sup> in 2001; however, in 2002 they rebounded to 191 m<sup>-2</sup>.
- Densities of Asiatic clams were low in all study areas. Zebra mussel densities were highest in Pool 13 showing a slight increase from 2001, whereas Pools 4, 8, and 26 and La Grange Pool zebra mussel densities decreased (<u>Table 2</u>).
- Over the last 9 years of sampling, Lake Pepin has consistently been the "hotspot" for mayflies in Pool 4 (<u>Table 3</u>). The impounded and backwater contiguous aquatic areas in Pools 8 and 13 supported the highest densities of mayflies (<u>Table 3</u>). Fingernail clam densities were highest in the impounded aquatic areas in Pools 4 (Lake Pepin), 8, 13, and 26 (<u>Table 4</u>) compared to other aquatic areas.
- The side channel aquatic area in La Grange Pool had the highest densities of fingernail clams—this is the highest densities of fingernail clams collected since

sampling began in 1992 in this area (Table 4).

- The backwater contiguous and impounded areas had higher densities of midges than other aquatic areas (<u>Table 5</u>) in all study areas. In Pool 26, midge densities reached their highest recorded level of 313 m<sup>-2</sup> in the impounded area compared to all other years and aquatic areas. While in La Grange Pool, the backwater contiguous area had the highest ever recorded density of midges since sampling began.
- In addition to the target taxa (mayflies, fingernail clams, midges, Asiatic clams, and zebra mussels), only Oligochaeta (aquatic worms and leeches) were present in samples more times than they were absent in all study areas except in Pool 26. In Pool 26, only midges were present in samples more times than they were absent.

- In 2001, the Open River Reach was dropped from the macroinvertebrate
  monitoring design because the previous 9 years of sampling have consistently
  indicated low densities of most taxa, especially mayflies (*Hexagenia* spp.) and
  fingernail clams (Sphaeriidae). Within this reach, habitat suitability for invertebrates
  in soft substrates is not expected to increase in the foreseeable future. We are
  currently investigating other methods for monitoring invertebrates in this river reach.
- The spring flood of 2001 made macroinvertebrate sampling exciting this year! River crests were the second or third highest on record for many areas of the Upper Mississippi River. Fighting high water and strong currents, the LTRMP field stations were able to complete all sampling. Macroinvertebrate sampling in 2001 produced a total of 1,610 mayflies, 3,289 fingernail clams, 1,773 midges, 5 Asiatic clams, and 7,838 zebra mussels from 557 total samples. This is a 47% decline in the total number of mayflies and a 32% decline in midges from 2000, yet these numbers are still within the range of numbers seen since sampling began in 1992. The total number of fingernail clams collected in 2001 increased 22% from 2000, whereas zebra mussel numbers increased by 64%. This is the highest total number of zebra mussels collected since sampling of zebra mussels began in 1995.
- The poolwide estimated mean densities of mayflies decreased between 2000 and 2001 in all study areas (<u>Table 2</u>; <u>Figures 2-4</u>). Pools 4 and 8 had the highest estimated mean density of mayflies, whereas in Pool 13 mean densities reached their lowest recorded level at 77 m<sup>-2</sup>. Changes in densities of fingernail clams and midges were variable among study areas with no consistent patterns. However, in Pool 13, density of midges dropped precipitously from 574 m<sup>-2</sup> in 2000 (the highest

level ever recorded by LTRMP) to 28 m<sup>-2</sup> in 2001.

- Zebra mussel densities were highest in Pools 4, 8, and 13 all of which increased in 2001, whereas Pool 26 and La Grange Pool decreased (<u>Table 2</u>). Pool 8's estimated density of 882 zebra mussels m-2 was the highest poolwide density ever recorded by LTRMP sampling.
- The impounded aquatic areas in Pools 4 (Lake Pepin), 8, 13, and 26 supported the
  highest densities of mayflies (<u>Table 3</u>) and fingernail clams (<u>Table 4</u>) compared to
  other aquatic areas. The impounded and backwater contiguous aquatic areas have
  consistently been the most productive areas for mayflies and fingernail clams over
  the years.
- The backwater contiguous areas in Pools 8, 13, and 26 and La Grange Pool had higher densities of midges than other aquatic areas (<u>Table 5</u>). In Pool 4, the highest density of midges was found in Lake Pepin. In Pool 26, midge densities reached their highest recorded level of 267 m<sup>-2</sup> in backwater contiguous areas compared to all other years and aquatic areas.
- Densities of zebra mussels were highest in the impounded areas in Pools 4, 8, and 13 (<u>Table 6</u>). Extremely low numbers of zebra mussels were found in Pool 26 (33 individuals collected) and La Grange Pool (1 individual collected).
- Overall, the high spring flood of 2001 did not affect LTRMP macroinvertebrate sampling. The flood's immediate effect on invertebrate abundance is unclear, but high flows with associated sediment scouring and deposition could have contributed to reduced densities of mayflies and midges. However, sampling in 2002 will provide the first opportunity to assess the long-term effects of the flood and of the experimental reduction in water levels conducted in Pool 8 during summer 2001.

- Macroinvertebrate sampling (n = 659) in 2000 produced a total of 3,446 mayflies, 2,694 fingernail clams, 5,503 midges, 8 Asiatic clams, and 4,771 zebra mussels.
- Mean densities of target taxa were weighted by strata selected for macroinvertebrate sampling (<u>Sauer 1998</u>) to estimate pool- or reach-wide means (<u>Table 2</u>; <u>Figures 2-4</u>). Pool 8 had the highest estimated mean numbers of mayflies and fingernail clams. Pool 13 had the highest densities of midges. The estimated mean number of mayflies increased between 1999 and 2000 in Pools 4 and 8. All

study areas showed slight declines in fingernail clams. No fingernail clams were found in the Open River Reach. Midge densities increased in Pools 13 and 26, the Open River Reach, and La Grange Pool.

- Mayfly densities have remained relatively stable in Pool 13 since the beginning of the monitoring program (<u>Table 2</u>).
- Zebra mussel densities were highest in Pools 8, 13, and 26 with some Ponar grab samples containing more than 200 individual zebra mussels (equivalent to 3,846 m<sup>-2</sup>). Zebra mussel densities increased tremendously in Pool 26 (<u>Table 2</u>).
- The impounded aquatic areas in Pools 4 (Lake Pepin) and 8 supported the highest numbers of mayflies (<u>Table 3</u>).
- Mean densities of fingernail clams were highest in Lake Pepin (Pool 4) and the impounded areas of Pools 8 and 26. The highest densities of fingernail clams in Pool 13 and La Grange Pool were found in the backwater contiguous aquatic areas (<u>Table 4</u>).
- The backwater contiguous areas in Pools 4, 8, 13, and 26 and La Grange Pool had higher densities of midges than other aquatic areas (<u>Table 5</u>). In the Open River Reach, the highest density of midges were found in the side channel aquatic areas.
- The impounded areas had the highest densities of zebra mussels in Pools 4, 8, and 13 (<u>Table 6</u>). Low numbers of zebra mussels were found in La Grange Pool—only four individuals were found during stratified random sampling (n = 99).
- Visual classification of sediments indicated that sample sites in Pools 4, 8, 13, and 26 and La Grange Pool were predominantly silt clay. Sampled substrates in the Open River Reach were mostly sand.

Content manager: <u>Jennie Sauer</u>



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**Tables** 

Table 2. Estimated mean numbers of mayflies, fingernail clams, midges, Asiatic clams, and zebra mussels per square meter by year and study area, weighted by areas of strata. For sample sizes, refer to <a href="Table 1">Table 1</a>. Midges were added to the sampling design in 1993 and zebra mussels in 1995. The wash frame sieve size was changed from a U.S. Standard Sieve no. 30 (0.595 mm), used in 1992, to a U.S. Standard Sieve no. 16 (1.18 mm) in 1993. SE=standard error.

Study reach	Year	Mayflies (m <sup>-2</sup> )		Fingernail clams (m <sup>-2</sup> )		Midges (m <sup>-2</sup> )	± 1 SE	Corbicula sp. (m <sup>-2</sup> )	± 1 SE	Zebra mussels (m <sup>-2</sup> )	± 1 SE
Pool 4	1992	59	18	47	19	_		0	0	_	_
	1993	128	36	74	11	318	39	0	0	_	
	1994	203	50	88	12	185	32	0	0	_	_
	1995	171	34	59	13	78	13	0	0	26	26
	1996	132	34	39	7	38	12	0	0	116	113
	1997	69	21	76	9	152	35	0	0	31	27
	1998	209	44	73	10	253	40	0	0	107	98
	1999	69	18	138	21	199	33	0	0	37	33
	2000	223	39	118	14	65	15	0	0	31	29
	2001	104	19	103	14	71	13	0	0	232	218
	2002	93	31	79	10	68	16	0	0	8	6
	2003 <sup>a</sup>	_	_	_	_	_	_	_	_	_	_

Sampling not conducted in 2003 because of budget constraints.

Study reach	Year	Mayflies (m <sup>-2</sup> )	± 1 SE	Fingernail clams (m <sup>-2</sup> )	± 1 SE	Midges (m <sup>-2</sup> )	± 1 SE	Corbicula sp. (m <sup>-2</sup> )	± 1 SE	Zebra mussels (m <sup>-2</sup> )	± 1 SE
Pool 8	1992	51	25	15	11	_	_	0	0	_	_
	1993	118	41	22	11	50	9	0	0	_	_
	1994	91	31	11	5	27	16	0	0	_	_
	1995	56	14	6	3	11	4	0	0	0	0
	1996	38	11	2	1	15	4	0	0	1	0
	1997	71	16	9	4	26	6	0	0	25	11
	1998	120	36	26	8	82	18	0	0	26	17
	1999	215	58	505	158	45	15	0	0	292	132
	2000	262	70	270	55	38	12	0	0	609	349
	2001	104	30	170	39	38	10	0	0	882	563
	2002	75	25	236	39	62	17	0	0	196	113
	2003	71	22	233	48	30	10	1	1	6	2

Study reach	Year	Mayflies (m <sup>-2</sup> )	± 1 SE	Fingernail clams (m <sup>-2</sup> )	± 1 SE	Midges (m <sup>-2</sup> )	± 1 SE	Corbicula sp. (m <sup>-2</sup> )	± 1 SE	Zebra mussels (m <sup>-2</sup> )	± 1 SE
Pool 13	1992	120	31	84	28	_	_	0	0	_	_
	1993	155	39	2596	494	509	95	0	0	_	
	1994	194	36	594	157	75	34	0	0	_	_
	1995	187	53	277	88	39	9	0	0	11	7
	1996	147	38	231	58	21	7	0	0	14	8
	1997	165	43	87	23	79	36	0	0	562	448
	1998	167	45	150	33	79	27	0	0	120	93
	1999	187	46	145	33	234	75	0	0	529	321
	2000	157	51	126	37	574	88	0	0	172	130
_	2001	77	19	333	121	28	14	0	0	428	169
	2002	221	54	366	86	191	47	0	0	448	200
	2003	77	25	243	55	138	27	<1	<1	2	2

Study reach	Year	Mayflies (m <sup>-2</sup> )	± 1 SE	Fingernail clams (m <sup>-2</sup> )	± 1 SE	Midges (m <sup>-2</sup> )	± 1 SE	Corbicula sp. (m <sup>-2</sup> )	± 1 SE	Zebra mussels (m <sup>-2</sup> )	± 1 SE
Pool 26	1992	21	9	15	9	_	_	2	1	_	_
	1993	7	2	1	1	10	2	0	0	_	_
	1994	21	6	5	3	14	8	1	1	_	_
	1995 <sup>a</sup>	_	_	_	_	_	_	_	_	_	_
	1996	13	10	0	0	18	9	0	0	0	0
	1997	16	8	1	1	13	6	0	0	1	1
	1998	25	16	4	4	5	2	4	3	29	24
	1999	28	15	1	1	9	4	1	1	2	2
	2000	27	11	0	0	27	8	2	2	109	105
	2001	7	3	1	1	30	8	<1	<1	7	6
	2002	44	22	1	<1	52	14	<1	<1	0	0
	2003 <sup>b</sup>	_	_	_	_	_	_		_	_	

<sup>&</sup>lt;sup>a</sup>Sampling not completed because of high water.

Study reach	Year	Mayflies (m <sup>-2</sup> )	± 1 SE	Fingernail clams (m <sup>-2</sup> )		Midges (m <sup>-2</sup> )	± 1 SE	Corbicula sp. (m <sup>-2</sup> )	± 1 SE	Zebra mussels (m <sup>-2</sup> )	± 1 SE
Open River Reach	1992	22	12	5	3	_	_	1	1	_	_
	1993 <sup>a</sup>										
	1994	19	9	1	1	8	4	2	1	_	_
	1995	12	6	0	0	14	5	2	1	2	2
	1996	11	6	0	0	5	2	1	1	0	0
	1997 <sup>a</sup>										
	1998	12	9	0	0	4	2	1	1	20	17
	1999	3	2	0	0	6	3	1	1	100	74

Sampling not conducted in 2003 because of budget constraints.

	2000	9	5	0	0	22	7	0	0	71	64
	2001 <sup>b</sup>	_		_		_		_		_	_

<sup>&</sup>lt;sup>a</sup>Sampling not conducted in 1993 or 1997 because of high water.

Study reach	Year	Mayflies (m <sup>-2</sup> )	± 1 SE	Fingernail clams (m <sup>-2</sup> )	± 1 SE	Midges (m <sup>-2</sup> )	± 1 SE	Corbicula sp. (m <sup>-2</sup> )	± 1 SE	Zebra mussels (m <sup>-2</sup> )	± 1 SE
La Grange Pool	1992	13	6	4	2	_		0	0	_	_
	1993	11	5	17	10	52	14	0	0	_	
	1994	27	8	51	13	57	10	10	3	_	
	1995	6	4	17	9	29	11	2	1	11	11
	1996	4	1	5	3	150	50	1	1	0	0
	1997	8	3	9	5	101	33	0	0	0	0
	1998	9	6	21	12	91	25	1	1	3	1
	1999	9	5	13	5	46	16	0	0	0	0
	2000	7	5	10	8	67	22	0	0	1	1
	2001	3	1	9	4	51	13	0	0	<1	<1
	2002	4	2	33	14	98	20	0	0	0	0
	2003 <sup>a</sup>		_		_	_	_	_	_	_	_

Sampling not conducted in 2003 because of budget constraints.

Content manager: Jennie Sauer

Sampling discontinued in 2001.



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# **Figures**

- Long Term Resource Monitoring Program study reaches for macroinvertebrate sampling
- 2. Estimated density of mayflies (number per square meter; ±1 standard error) by study area, weighted by area of strata
- Estimated density of fingernail clams (number per square meter; ±1 standard error) by study area, weighted by area of strata
- 4. Estimated density of midges (number per square meter; ±1 standard error) by study area, weighted by area of strata
- 5. Estimated density of zebra mussels (number per square meter; ±1 standard error) by study area, weighted by area of strata

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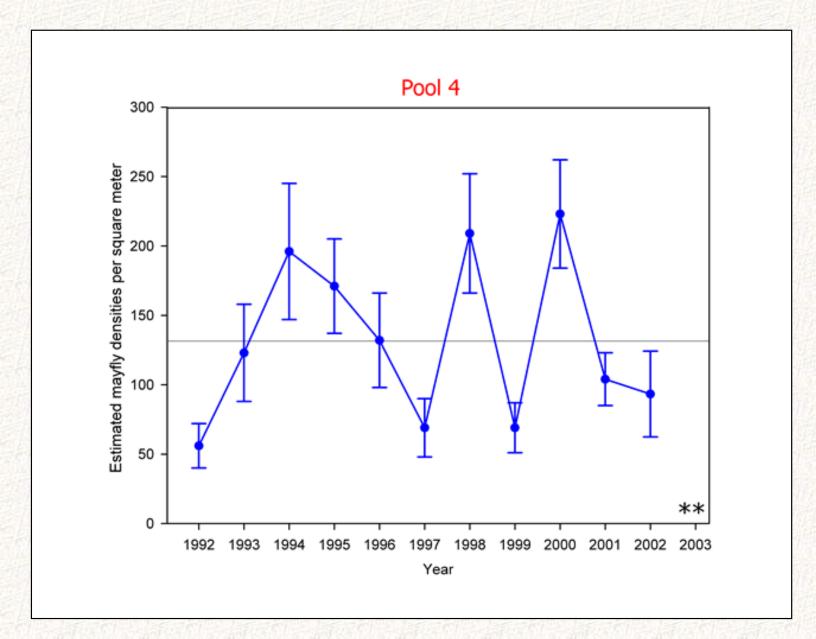
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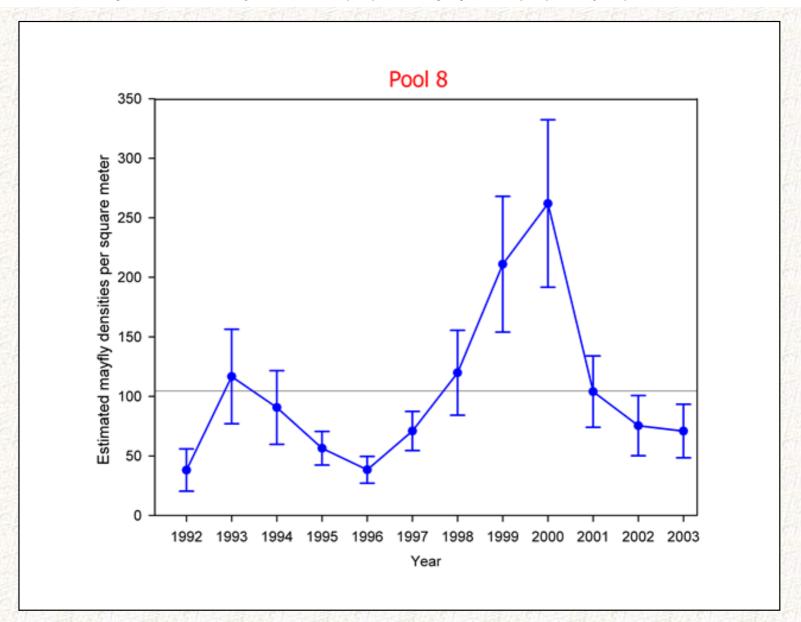


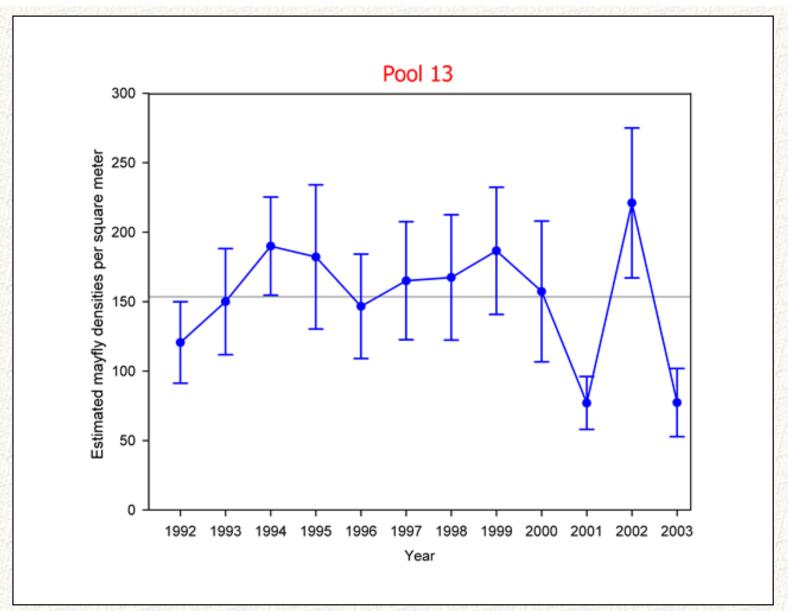
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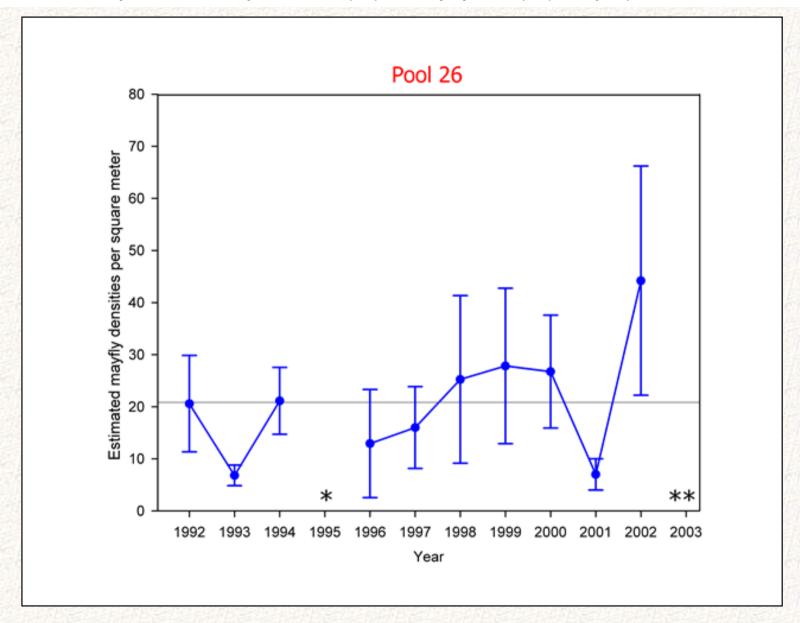
Figure 2. Estimated density of mayflies (number per square meter; ±1 standard error) by study area, weighted by area of strata. The wash frame sieve size was changed from a U.S. Standard Sieve no. 30 (0.595 mm), used in 1992, to a U.S. Standard Sieve no. 16 (1.18 mm) in 1993. Horizontal line indicates grand mean.



<sup>\*\*</sup>Sampling not conducted in 2003 because of budget constraints.

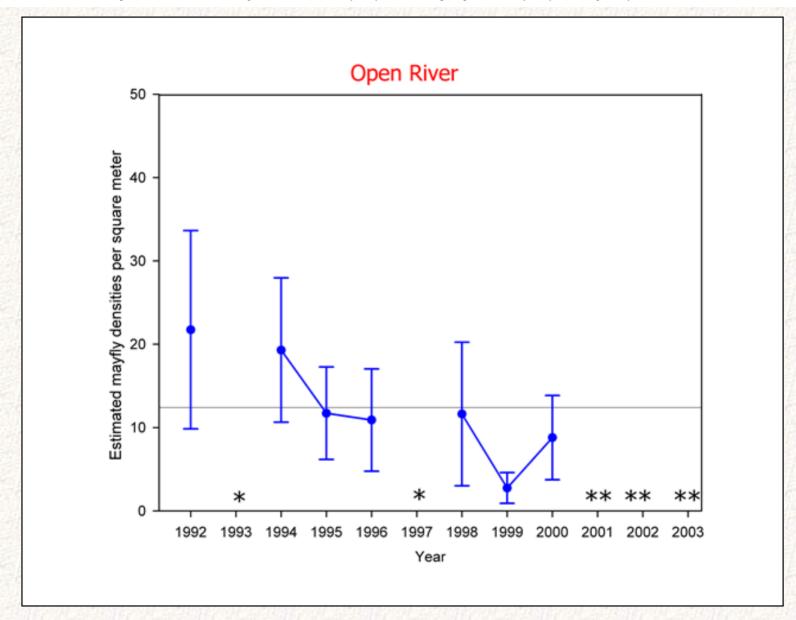






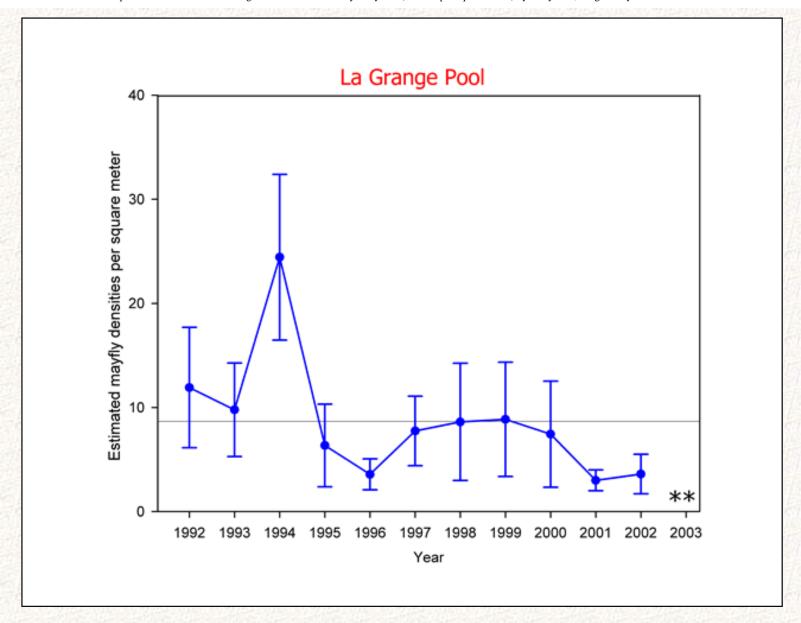
<sup>\*</sup>Sampling not completed because of high water.

<sup>\*\*</sup>Sampling not conducted in 2003 because of budget constraints.



<sup>\*</sup>Sampling not completed because of high water.

<sup>\*\*</sup>Sampling discontinued in 2001.



\*\*Sampling not conducted in 2003 because of budget constraints.

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# **Zebra Mussels**

Dead zebra mussels found in a Ponar grab sample in Pool 8 of the Upper Mississippi River System.

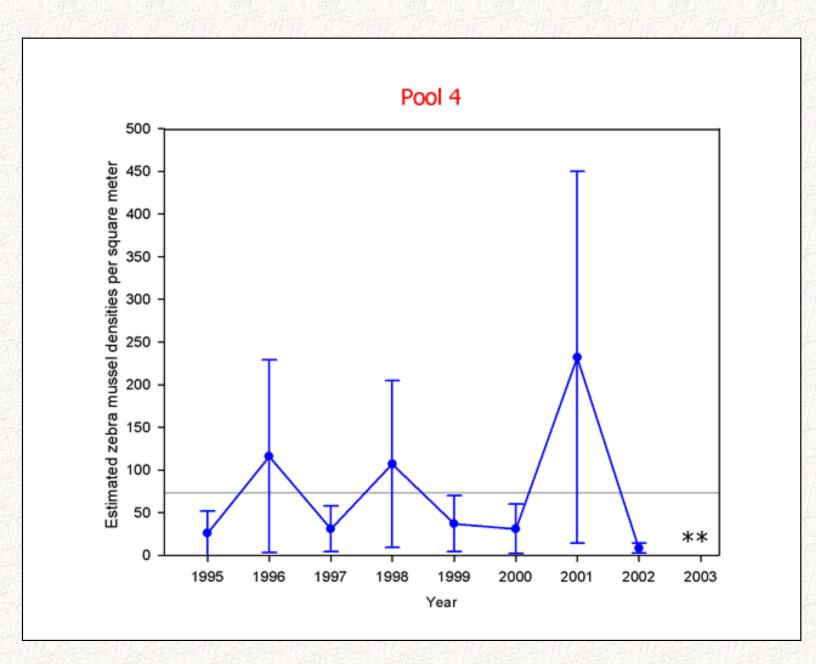


Photo: Jennie Sauer, Upper Midwest Environmental Sciences Center

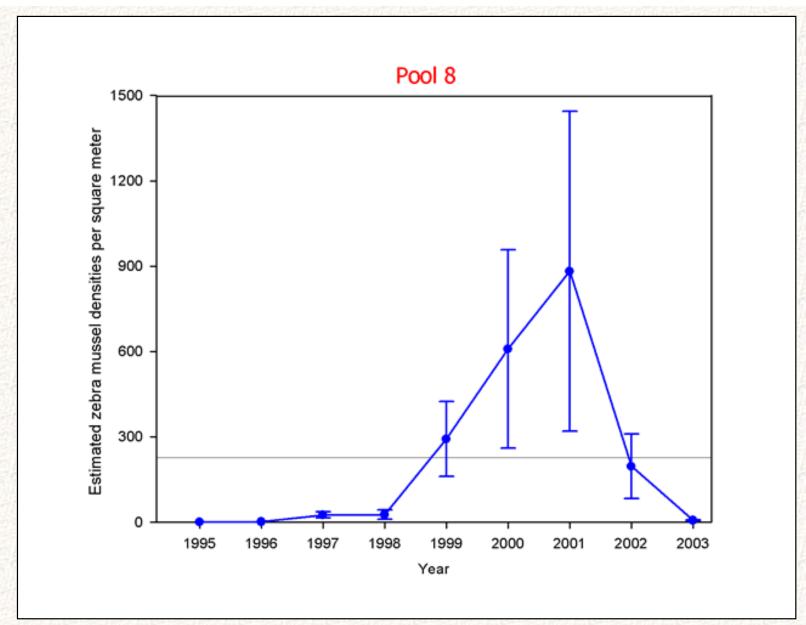


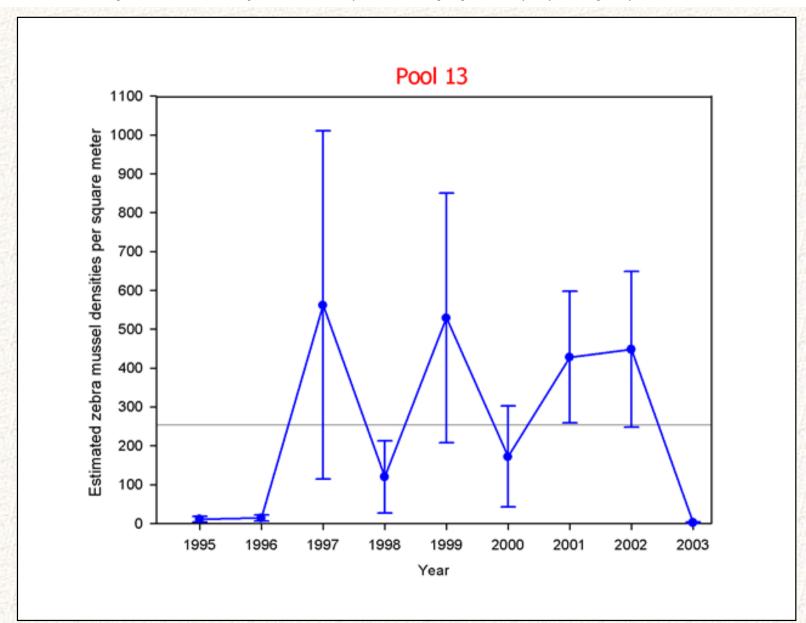
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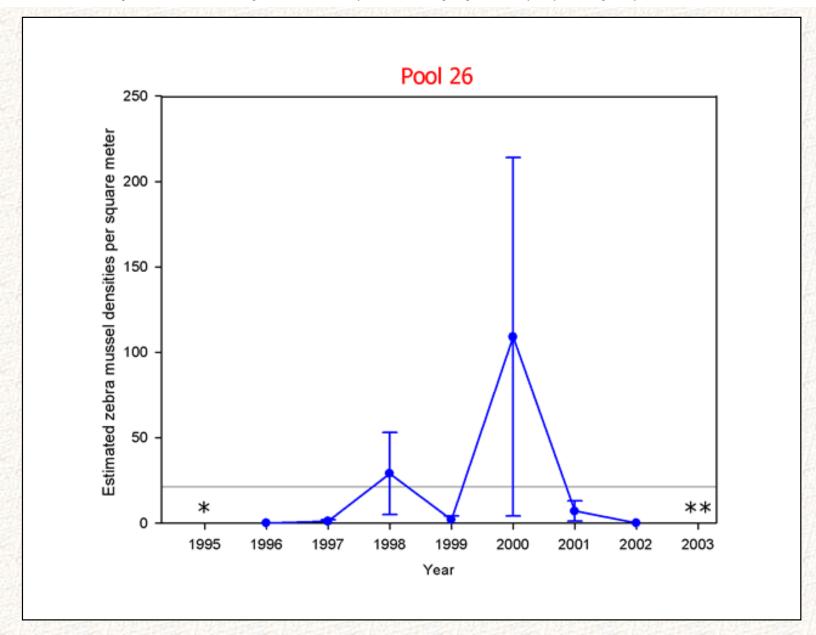
**Figure 5.** Estimated density of zebra mussels (number per square meter; ±1 standard error) by study area, weighted by area of strata. Horizontal line indicates grand mean.



<sup>\*\*</sup>Sampling not conducted in 2003 because of budget constraints.

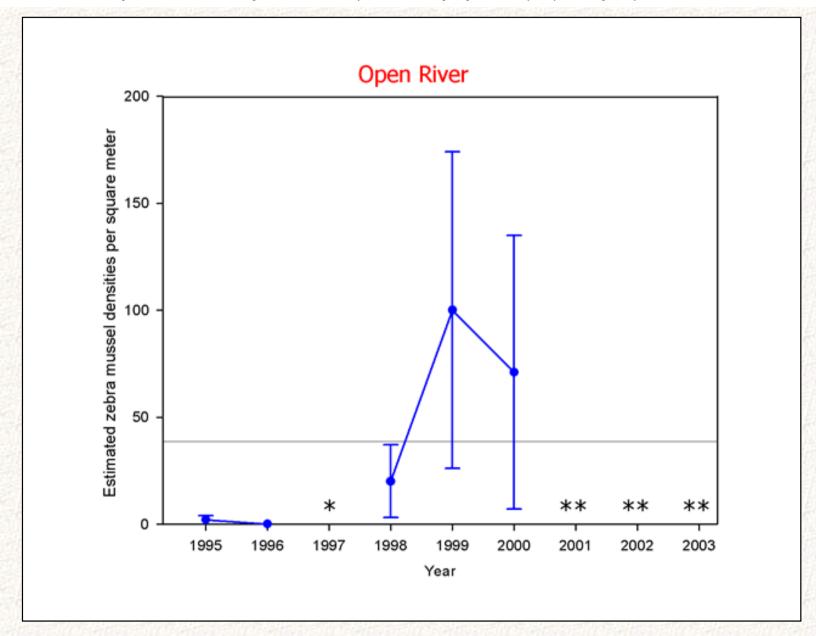






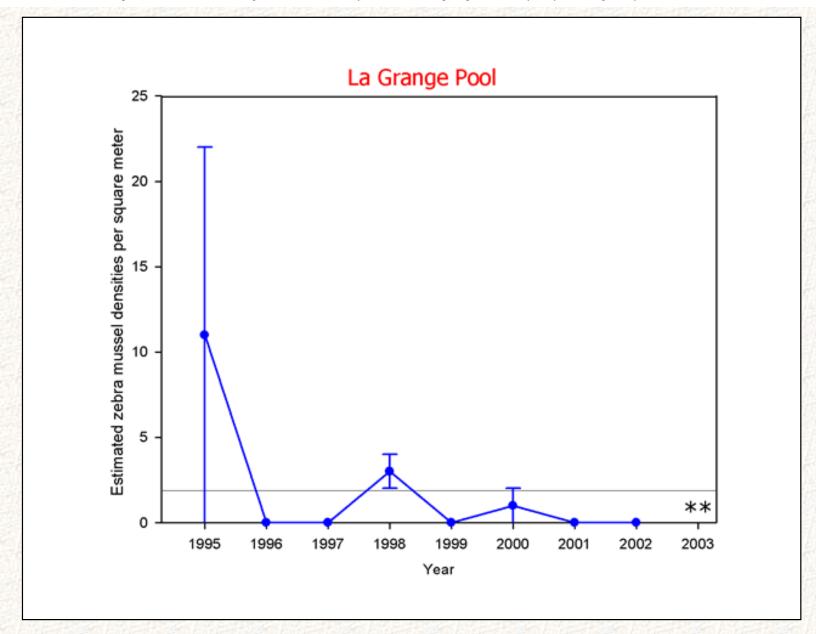
<sup>\*</sup>Sampling not completed because of high water.

<sup>\*\*</sup>Sampling not conducted in 2003 because of budget constraints.



<sup>\*</sup>Sampling not completed because of high water.

<sup>\*\*</sup>Sampling discontinued in 2001.



\*\*Sampling not conducted in 2003 because of budget constraints.

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**Table 3.** Mean number of mayflies per square meter by study reach and aquatic strata. For sample sizes, refer to <a href="Table 1">Table 1</a>. The wash frame sieve size was changed from a U.S. Standard Sieve no. 30 (0.595 mm), used in 1992, to a U.S. Standard Sieve no. 16 (1.18 mm) in 1993. SE=standard error.

Study reach	Year	Backwater contiguous	± 1 SE	Impounded <sup>a</sup>	± 1 SE	Side channel	± 1 SE	Main channel border	± 1 SE
Pool 4	1992	104	22	48	15	30	11	32	28
	1993	74	18	150	42	29	21	2	2
	1994	104	21	236	54	104	102	25	25
	1995	56	13	218	39	21	12	58	58
	1996	76	23	163	41	2	2	2	2
	1997	80	19	76	24	0	0	3	2
	1998	148	26	242	43	2	2	182	179
	1999	65	15	74	17	63	49	0	0
	2000	79	18	284	46	61	45	2	2
	2001	39	11	135	24	0	0	0	0
	2002	75	24	110	36	12	12	0	0
	2003 <sup>b</sup>	_	_	_	_	_	_	_	_

<sup>&</sup>lt;sup>a</sup> Impounded area for Pool 4 is Lake Pepin, a Tributary Delta Lake

Sampling not conducted in 2003 because of budget constraints.

Study reach		Backwater contiguous	± 1 SE	Impounded	± 1 SE	Side channel	1 1	Main channel border	± 1 SE
Pool 8	1992	51	14	47	26	11	6	15	6
	1993	149	65	124	25	111	61	0	0

19	994	105	30	111	35	62	36	2	2
19	995	62	20	82	16	8	7	2	2
19	996	22	11	64	15	11	6	0	0
19	997	87	22	82	15	53	17	6	6
19	998	111	32	146	34	115	58	8	8
19	999	133	47	239	42	339	134	2	2
20	000	52	17	395	79	285	126	58	51
20	001	111	24	130	34	52	27	51	32
20	2002	45	16	107	24	32	18	79	77
20	003	65	29	99	24	34	17	14	8

Study reach	Year	Backwater contiguous	± 1 SE	Impounded	± 1 SE	Side channel	± 1 SE	Main channel border	± 1 SE
Pool 13	1992	75	16	200	45	54	25	35	15
	1993	91	24	223	42	147	57	64	48
	1994	392	60	138	33	23	11	1	1
	1995	154	32	250	56	135	62	110	88
	1996	186	34	95	21	407	156	4	3
	1997	235	43	138	30	154	92	88	43
	1998	219	48	181	41	140	92	19	13
	1999	136	40	263	37	66	43	165	89
	2000	47	22	220	38	232	94	164	125
	2001	73	20	112	20	10	7	28	22
	2002	314	68	246	58	89	43	22	15
	2003	103	37	83	18	10	7	53	29

Study reach	Year	Backwater contiguous	± 1 SE	Impounded	± 1 SE	Side channel	± 1 SE	Main channel border	± 1 SE
Pool 26	1992	1	1	48	23	21	10	21	9
	1993	38	10	121	37	0	0	0	0
	1994	156	33	118	36	9	4	5	3

1995	5	3	21	11	a	_	a	_
1996	8	4	24	9	18	12	11	11
1997	120	40	55	15	18	15	0	0
1998	74	49	38	23	26	19	18	10
1999	21	19	21	6	22	12	32	16
2000	3	2	24	9	32	11	28	12
2001	7	4	54	18	17	8	0	0
2002	9	4	19	5	10	4	65	33
2003 <sup>b</sup>	_	_	_	_	_	_	_	_

<sup>&</sup>lt;sup>a</sup>Sampling not completed because of high water.

Study reach	Year	Side channel		Main channel border	± 1 SE
Open River Reach	1992	48	20	18	11
	1993 <sup>a</sup>	_		_	
	1994	7	3	21	9
	1995	10	3	12	6
	1996	17	7	10	6
	1997 <sup>a</sup>	_	_	_	_
	1998	15	10	11	8
	1999	3	2	3	2
	2000	17	6	8	5
	2001 <sup>b</sup>	_	_	_	_

<sup>&</sup>lt;sup>a</sup>Sampling not conducted in 1993 or 1997 because of high water.

r			and the control of the control of						1
Ŀ			Backwater	±		±	Main channel	±	Ŕ
100	Study reach	Year	contiguous	1 SE	Side channel	1 SE	border	1 SE	

Sampling not conducted in 2003 because of budget constraints.

Sampling discontinued in 2001.

La Grange Pool	1992	21	10	9	3	8	4
	1993	17	7	22	7	6	3
	1994	45	13	67	15	12	5
	1995	2	1	13	4	8	5
	1996	5	2	29	7	1	1
	1997	14	6	12	3	4	2
	1998	12	7	8	4	7	5
	1999	12	7	9	3	7	5
	2000	6	6	10	4	8	5
	2001	5	2	8	4	2	1
	2002	5	4	12	3	2	1
	2003 <sup>b</sup>	_	_	_		_	

<sup>&</sup>lt;sup>a</sup>Sampling not conducted in 2003 because of budget constraints.

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**Table 4.** Mean number of fingernail clams per square meter by study reach and aquatic strata. For sample sizes, refer to <a href="Table 1">Table 1</a>. The wash frame sieve size was changed from a U.S. Standard Sieve no. 30 (0.595 mm), used in 1992, to a U.S. Standard Sieve no. 16 (1.18 mm) in 1993. SE=standard error.

Study reach	Year	Backwater contiguous	± 1 SE	Impounded	± 1 SE	Side channel	± 1 SE	Main channel border	± 1 SE
Pool 4	1992	24	6	58	23	7	3	15	9
	1993	13	3	94	13	2	2	2	2
	1994	23	6	111	15	2	2	0	0
	1995	8	3	79	16	12	10	7	4
	1996	13	5	51	9	3	2	0	0
	1997	5	2	103	11	2	2	5	5
	1998	24	7	94	12	0	0	9	9
	1999	21	6	185	27	0	0	0	0
	2000	30	5	156	18	2	2	0	0
	2001	18	4	138	18	6	6	0	0
	2002	19	5	104	12	0	0	0	0
	2003 <sup>b</sup>	_		_		_			

<sup>&</sup>lt;sup>a</sup> Impounded area for Pool 4 is Lake Pepin, a Tributary Delta Lake

Sampling not conducted in 2003 because of budget constraints.

Study reach	Year	Backwater contiguous	± 1 SE	Impounded	± 1 SE	Side channel	± 1 SE	Main channel border	± 1 SE
Pool 8	1992	11	4	18	15	1	1	1	1

1993	41	31	21	4	7	4	4	3
1994	14	8	12	4	10	5	0	0
1995	10	6	7	2	0	0	4	4
1996	2	1	3	1	1	1	0	0
1997	10	2	4	1	17	8	13	9
1998	23	6	34	8	18	10	13	13
1999	75	27	864	206	321	202	131	129
2000	58	26	496	85	83	35	17	8
2001	79	22	276	48	59	36	81	44
2002	58	15	378	38	194	78	31	20
2003	81	30	371	54	167	67	40	22

Study reach	Year	Backwater contiguous	± 1 SE	Impounded	± 1 SE	Side channel		Main channel border	± 1 SE
Pool 13	1992	114	32	82	16	81	43	10	5
	1993	87	31	5856	1067	110	50	176	129
	1994	176	39	1270	338	44	21	3	2
	1995	117	29	525	164	47	25	59	37
	1996	98	21	413	90	92	27	88	73
	1997	102	21	111	29	33	20	23	10
	1998	178	45	194	30	37	21	35	26
	1999	95	27	260	52	15	10	10	9
	2000	170	63	139	22	85	52	10	8
	2001	93	34	591	152	25	19	342	320
	2002	194	45	609	84	87	57	238	218
	2003	100	36	468	84	66	52	19	10

Study reach	Year	Backwater contiguous	± 1 SE	Impounded	± 1 SE	Side channel	± 1 SE	Main channel border	± 1 SE
Pool 26	1992	3	2	95	39	1	1	17	12
	1993	8	3	22	9	0	0	0	0
	1994	14	7	41	23	0	0	4	3

1995	1	1	1	1	a	_	a	_
1996	2	1	3	1	0	0	0	0
1997	5	3	7	4	1	1	0	0
1998	3	3	11	10	1	1	5	5
1999	2	2	6	3	1	1	1	1
2000	0	0	4	2	0	0	0	0
2001	4	2	9	4	3	3	0	0
2002	8	3	24	7	0	0	0	0
2003 <sup>b</sup>	_		_		_		_	_

<sup>&</sup>lt;sup>a</sup>Sampling not completed because of high water.

Study reach	Year	Side channel	± 1 SE	Main channel border	± 1 SE
Open River Reach	1992	14	7	4	3
	1993 <sup>a</sup>	_		_	_
	1994	0	0	1	1
	1995	0	0	0	0
	1996	0	0	0	0
	1997 <sup>a</sup>	_		_	_
	1998	0	0	0	0
	1999	0	0	0	0
	2000	0	0	0	0
	2001 <sup>b</sup>	_	_	_	_

<sup>&</sup>lt;sup>a</sup>Sampling not conducted in 1993 or 1997 because of high water.

Study reach Year contiguous	II .	Side channel	ll .	Main channel border	± 1 SE
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Sampling not conducted in 2003 because of budget constraints.

Sampling discontinued in 2001.

La Grange Pool	1992	4	3	11	6	3	2
	1993	14	8	49	28	17	9
	1994	40	14	62	11	59	12
	1995	6	3	33	12	20	12
	1996	9	5	3	1	3	2
	1997	22	12	11	4	3	2
	1998	8	3	34	10	25	16
	1999	18	7	32	9	9	4
	2000	21	18	4	2	6	4
	2001	17	6	17	7	5	2
	2002	43	24	74	20	25	9
	2003 <sup>a</sup>	_	_	_	_	_	_
a							

Sampling not conducted in 2003 because of budget constraints.

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Table Mean number of midges per square meter by study reach and aquatic
strata. For sample sizes, refer to <u>Table 1</u>. SE=standard error.

Study reach	Year	Backwater contiguous	± 1 SE	Impounded <sup>a</sup>	± 1 SE	Side channel	± 1 SE	Main channel border	± 1 SE
Pool 4	1993	203	32	364	38	87	50	40	34
	1994	233	61	182	22	135	80	23	21
	1995	116	17	78	14	12	5	10	6
	1996	47	12	37	11	33	17	25	13
	1997	81	20	190	43	5	4	7	7
	1998	98	12	324	51	24	14	2	2
	1999	107	22	243	36	33	17	56	46
	2000	82	14	59	12	77	22	77	65
	2001	32	9	88	15	31	20	0	0
	2002	90	20	68	15	52	36	0	0
	2003 <sup>b</sup>		_	_		_			_

<sup>&</sup>lt;sup>a</sup> Impounded area for Pool 4 is Lake Pepin, a Tributary Delta Lake

Sampling not conducted in 2003 because of budget constraints.

Study reach	Year	Backwater contiguous	± 1 SE	Impounded	± 1 SE	Side channel		Main channel border	± 1 SE
Pool 8	1993	40	11	66	8	42	13	10	8
	1994	38	11	12	7	57	50	3	2
	1995	12	4	13	4	9	7	0	0
	1996	19	6	20	5	1	1	4	3
	1997	20	7	39	7	10	6	6	6

1998	100	18	82	11	83	40	33	15
1999	46	16	53	14	24	7	38	34
2000	84	23	20	7	32	13	19	12
2001	97	25	26	7	8	4	0	0
2002	72	13	68	17	36	18	54	32
2003	92	32	13	3	6	2	2	2

Study reach	Year	Backwater contiguous	± 1 SE	Impounded	± 1 SE	Side channel	± 1 SE	Main channel border	± 1 SE
Pool 13	1993	237	56	916	130	18	9	190	135
	1994	144	43	43	33	8	4	50	40
	1995	93	18	19	7	2	2	3	2
	1996	53	14	5	3	12	8	4	4
	1997	213	99	19	6	0	0	10	9
	1998	148	37	61	29	3	2	33	22
	1999	698	220	11	4	5	4	4	4
	2000	1664	223	63	30	25	18	8	4
	2001	56	14	22	21	3	3	0	0
	2002	570	137	12	6	3	2	0	0
	2003	416	80	4	2	0	0	0	0

Study reach	Year	Backwater contiguous	± 1 SE	Impounded	± 1 SE	Side channel	± 1 SE	Main channel border	± 1 SE
Pool 26	1993	81	17	136	26	0	0	0	0
	1994	90	26	46	15	2	1	9	8
	1995	48	18	31	15	a	_	a 	_
	1996	112	37	48	10	6	4	11	7
	1997	106	46	39	11	0	0	6	4
	1998	34	11	30	12	1	1	1	1
	1999	59	19	42	10	9	6	1	1
	2000	82	14	78	15	27	8	17	6

	2001	267	68	149	22	18	6	0	0
	2002	255	58	313	52	19	9	28	9
2	2003 <sup>b</sup>	_	_	_	_	_	_	_	_

<sup>&</sup>lt;sup>a</sup>Sampling not completed because of high water.

Study reach	Year	Side channel	± 1 SE	Main channel border	± 1 SE
Open River Reach	1993 <sup>a</sup>	_	_	_	
	1994	4	2	8	4
	1995	41	12	10	4
	1996	21	4	3	2
	1997 <mark>a</mark>	_		_	_
	1998	5	2	4	2
	1999	2	1	6	3
	2000	119	30	9	4
	2001 <sup>b</sup>	_	_	_	_

<sup>&</sup>lt;sup>a</sup>Sampling not conducted in 1993 or 1997 because of high water.

Study reach	Year	Backwater contiguous	± 1 SE	Side channel	± 1 SE	Main channel border	± 1 SE
La Grange Pool	1993	92	22	26	5	27	10
	1994	51	9	75	14	58	10
	1995	54	24	50	14	15	4
	1996	97	21	136	38	175	64
	1997	188	58	55	27	64	22
	1998	244	68	21	9	25	6
	1999	120	43	25	7	13	4

Sampling not conducted in 2003 because of budget constraints.

<sup>&</sup>lt;sup>b</sup>Sampling discontinued in 2001.

2000	177	62	25	6	18	4
2001	132	30	73	26	12	4
2002	264	51	90	31	21	5
2003 <sup>a</sup>	_	_	_	_	_	_

<sup>&</sup>lt;sup>a</sup>Sampling not conducted in 2003 because of budget constraints.

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**Table 6.** Mean number of zebra mussels per square meter by study reach and aquatic strata. For sample sizes, refer to <u>Table 1</u>. SE=standard error.

Study reach	Year	Backwater contiguous	± 1 SE	Impounded <sup>a</sup>	± 1 SE	Side channel	± 1 SE	Main channel border	± 1 SE
Pool 4	1995	1	1	34	34	0	0	17	17
	1996	0	0	159	156	2	2	13	10
	1997	3	2	1	1	7	5	673	603
	1998	1	1	110	110	19	17	609	396
	1999	17	10	45	40	21	17	17	14
	2000	1	1	14	14	16	11	440	423
	2001	2	1	321	302	0	0	0	0
	2002	40	25	1	1	0	0	23	23
	2003 <sup>b</sup>	_	_	_	_	_	_	_	_

Impounded area for Pool 4 is Lake Pepin, a Tributary Delta Lake

Sampling not conducted in 2003 because of budget constraints.

Study reach	Year	Backwater contiguous	± 1 SE	Impounded	± 1 SE	Side channel		Main channel border	± 1 SE
Pool 8	1995	0	0	0	0	1	1	0	0
	1996	0	0	1	1	1	1	0	0
	1997	3	2	37	15	29	17	6	4
	1998	1	1	43	27	1	1	56	39
	1999	34	21	1553	1115	326	182	81	54
	2000	1	1	825	413	1014	690	225	219
	2001	8	6	1609	953	543	536	26	14

15 M 15 M	2002	14	14	337	178	158	124	12	8	
	2003	0	0	12	3	2	2	0	0	E

Study reach	Year	Backwater contiguous	± 1 SE	Impounded	± 1 SE	Side channel	± 1 SE	Main channel border	± 1 SE
Pool 13	1995	1	1	17	10	5	5	18	15
	1996	6	6	15	5	18	18	28	15
	1997	2	1	755	685	7	6	1762	1141
	1998	25	25	157	111	158	158	203	148
	1999	171	155	974	503	12	6	399	399
	2000	1	1	223	144	246	180	360	359
	2001	4	2	898	306	3	3	308	271
	2002	3	2	962	394	268	251	31	20
	2003	0	0	3	2	3	3	5	5

Study reach	Year	Backwater contiguous	± 1 SE	Impounded	± 1 SE	Side channel	± 1 SE	Main channel border	± 1 SE
Pool 26	1995	0	0	4	3	_a	_	_a	_
	1996	0	0	11	11	0	0	0	0
	1997	0	0	0	0	2	1	1	1
	1998	0	0	418	310	0	0	25	23
	1999	0	0	7	7	0	0	2	2
	2000	0	0	0	0	5	2	175	170
	2001	0	0	6	4	14	13	4	3
	2002	0	0	0	0	0	0	0	0
	2003 <sup>b</sup>	_	_	_	_	_		_	_

<sup>&</sup>lt;sup>a</sup>Sampling not completed because of high water.

Sampling not conducted in 2003 because of budget constraints.

Study reach	Year	Side channel	± 1 SE	Main channel border	± 1 SE
Open River Reach	1995	0	0	3	2
	1996	3	2	0	0
	1997 <sup>a</sup>	_	_	_	_
	1998	1	0	22	19
	1999	1	1	113	84
	2000	16	15	78	71
	2001 <sup>b</sup>	_	_	_	_

<sup>&</sup>lt;sup>a</sup> Sampling not conducted in 1997 because of high water.

Study reach	Year	Backwater contiguous	± 1 SE	Side channel	± 1 SE	Main channel border	± 1 SE
La Grange Pool	1995	0	0	2	2	16	16
	1996	0	0	1	1	1	1
	1997	0	0	0	0	0	0
	1998	0	0	8	4	3	1
	1999	0	0	0	0	0	0
	2000	0	0	0	0	2	2
	2001	0	0	0	0	<1	<1
	2002	0	0	0	0	0	0
	2003 <sup>a</sup>	_		_		_	

<sup>&</sup>lt;sup>a</sup>Sampling not conducted in 2003 because of budget constraints.

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<sup>&</sup>lt;sup>b</sup>Sampling discontinued in 2001.



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## **Tables**

- 1. Number of random sample sites for macroinvertebrates by study reach and aquatic strata.
- 2. Estimated mean numbers of mayflies, fingernail clams, midges, Asiatic clams, and zebra mussels per square meter by year and study area, weighted by areas of strata.
- 3. Mean number of mayflies per square meter by study reach and aquatic strata.
- 4. Mean number of fingernail clams per square meter by study reach and aquatic strata.
- 5. Mean number of midges per square meter by study reach and aquatic strata.
- 6. Mean number of zebra mussels per square meter by study reach and aquatic strata.

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**Figure 1.** Long Term Resource Monitoring Program study reaches for macroinvertebrate sampling.

- Pool 4
- Pool 8
- Pool 13

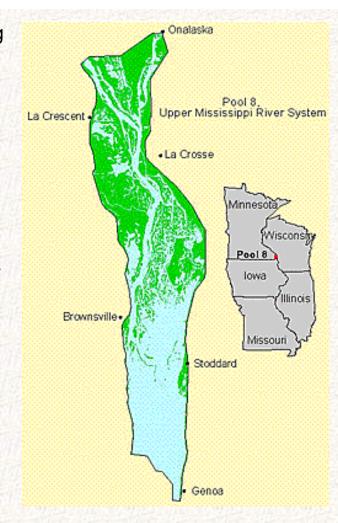
- Pool 26
- Open River Reach
- La Grange Pool

Navigation Pool 4 is 73 km (44 river miles) long and includes 14,700 ha (36,300 acres) of aquatic habitat. It is located between Lock and Dam 3 (above Red Wing, Minnesota) and Lock and Dam 4 (Alma, Wisconsin). Major tributaries include the Cannon and Vermillion Rivers on the Minnesota side and the much larger Chippewa River on the Wisconsin side. Lake

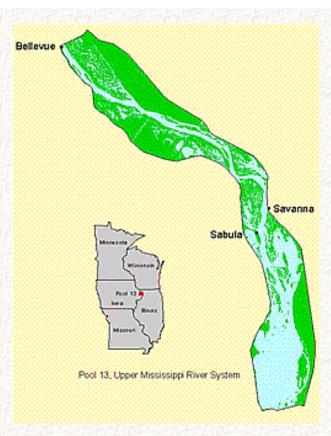


Pepin, a riverine lake created by the Chippewa River delta, is located in the middle of Pool 4. The location of Lake Pepin divides the rest of the pool into upper Pool 4 and lower Pool 4. The smaller backwaters of upper Pool 4 have been degraded by sedimentation, whereas the larger backwaters of lower Pool 4 provides much better habitat for vegetation.

**Navigation** Pool 8 is 39 km (23 river miles) long and is bounded by Lock and Dam 7 (Dresbach, Minnesota) to the north and Lock and Dam 8 (Genoa, Wisconsin) to the south. It encompasses 9,000 ha (22,100 acres) of aquatic habitat. Major tributaries include the Black, Root, and La Crosse Rivers. The upper section of Pool 8 has high bank islands adjacent to the main channel, deep secondary channels, and backwater sloughs. The middle section contains low islands, braided channels, and small backwater sloughs. The lower section is a large open expanse of water.



Navigation Pool 13 is 52 km (34 river miles) in length and is bounded by Lock and Dam 12 (Bellevue, Iowa) to the north and Lock and Dam 13 (Fulton, Illinois) to the south. It encompasses 11,400 ha (28,100 acres) of aquatic habitat. Similar to pools upstream, Pool 13 contains many high bank islands adjacent to the main channel in the upper section, braided backwater channels and sloughs in the middle section, and a large open lake-like area in the lower section of the pool. Major tributaries include the Apple and Plum Rivers on the Illinois side and Maquoketa and Elk Rivers on the lowa side.



# The Navigation Pool 26

study area includes water bodies along the Upper Mississippi River from Lock and Dam 25 (Winfield, Missouri) to Lock and Dam 26 (Alton, Illinois)–63 km (39 river miles) long—and the lower Illinois River from its confluence with the Mississippi River north to Illinois River mile 12. This reach of the two rivers is



bordered by high bluffs on the Illinois side and low elevation floodplain on the Missouri side. The reach encompasses 9,500 ha (23,700 acres) of aquatic habitat. Presently, most of the backwaters of the lower Illinois River are isolated from the river by low levees so as to decrease sedimentation and allow management for waterfowl. Likewise, many of the secondary channels of the Mississippi River are isolated from the river on

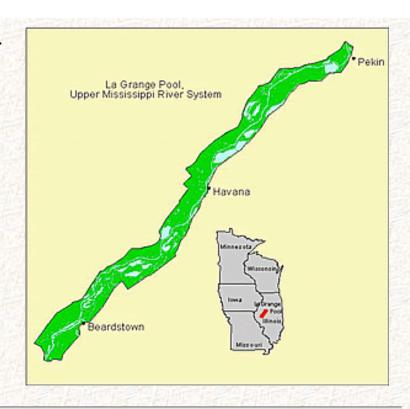
the upstream side to create backwaters and to reduce sedimentation.

The **Open River Reach** study area in the open river is 84 km (52 river miles) long. The study reach has approximately 7,241 ha (17,893 acres) of aguatic habitat in the form of open water, sand and mud flats, and swamps and marsh. The floodplain is extensively disconnected from the mainstem river by levees. Many of the islands are now joined to the mainland and most side channels contain closing structures and become disconnected from the mainstem at moderately low flows. This river reach is characterized by turbid water, high water velocities, and sand substrate; thus, the aquatic communities are dominated by more obligate riverine species than the pooled portion of the Upper Mississippi River. Major tributaries to the Open River study area are the Little River Diversion Channel in Missouri, and the Big Muddy Rivers and Cache River Diversion Channel in Illinois.



La Grange Pool on the Illinois River is about 130 km (80 river miles) long and encompasses 10,750 ha (26,500 acres) of aquatic habitat. It is bounded by Peoria Lock and Dam to the north and La Grange Lock and Dam to the south. This reach has the highest proportion of backwaters, except for Pool 4, but these backwaters are highly degraded by excessive sedimentation over the last 150 years. Many backwaters are isolated by low levees to enhance waterfowl habitat management. Major tributaries include the

Sangmon, Mackinaw, and LaMoine Rivers.



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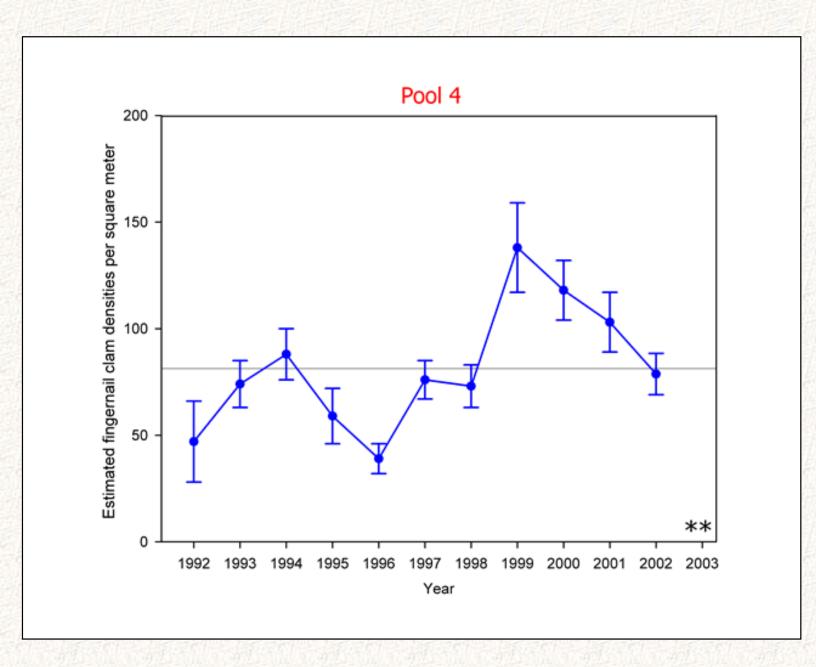
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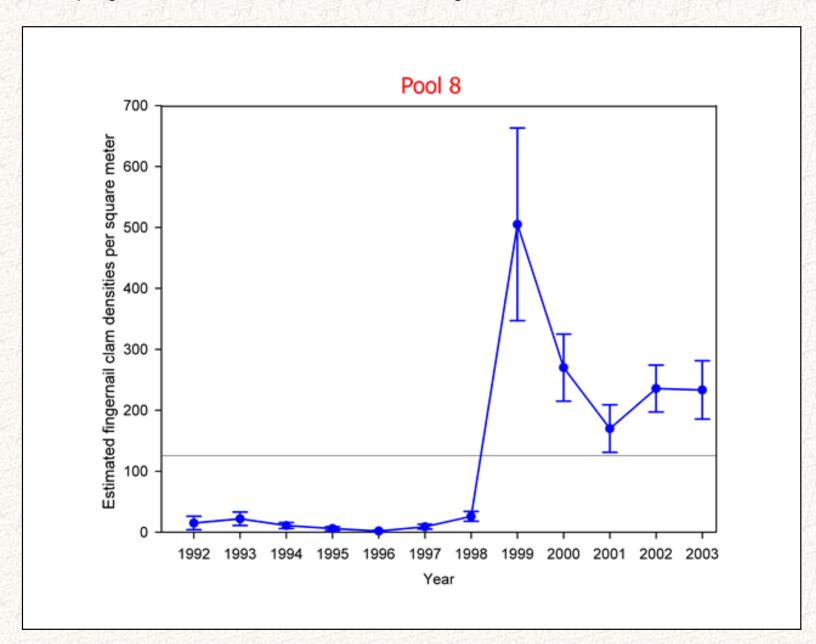


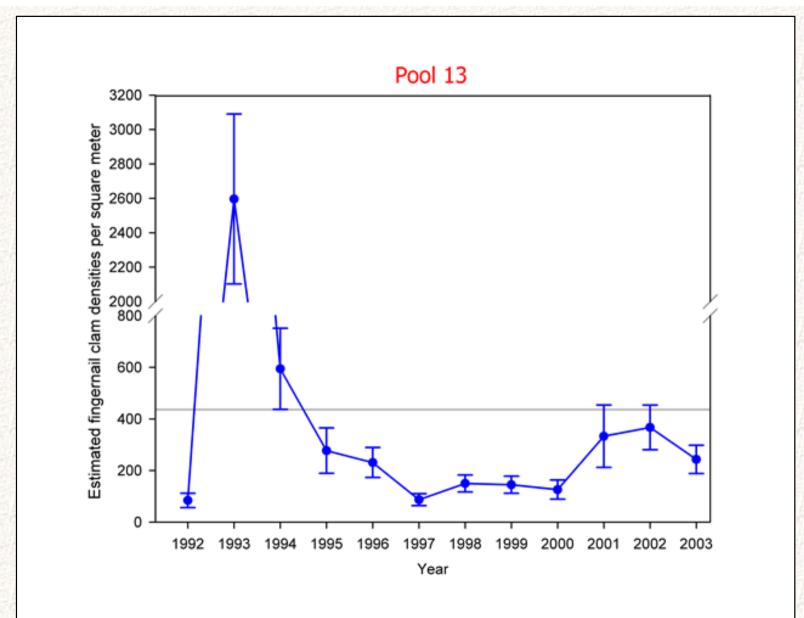
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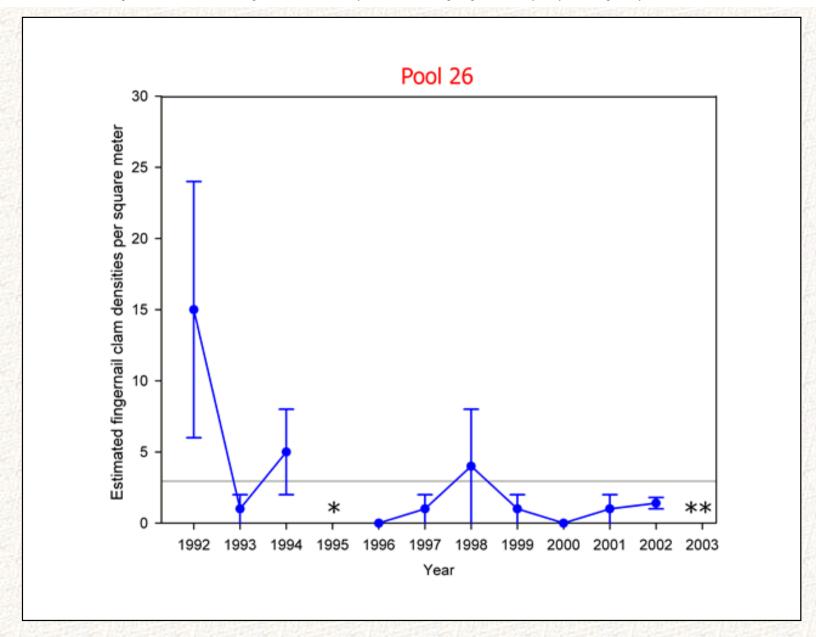
**Figure 3.** Estimated density of fingernail clams (number per square meter; ±1 standard error) by study area, weighted by area of strata. The wash frame sieve size was changed from a U.S. Standard Sieve no. 30 (0.595 mm), used in 1992, to a U.S. Standard Sieve no. 16 (1.18 mm) in 1993. Horizontal line indicates grand mean.



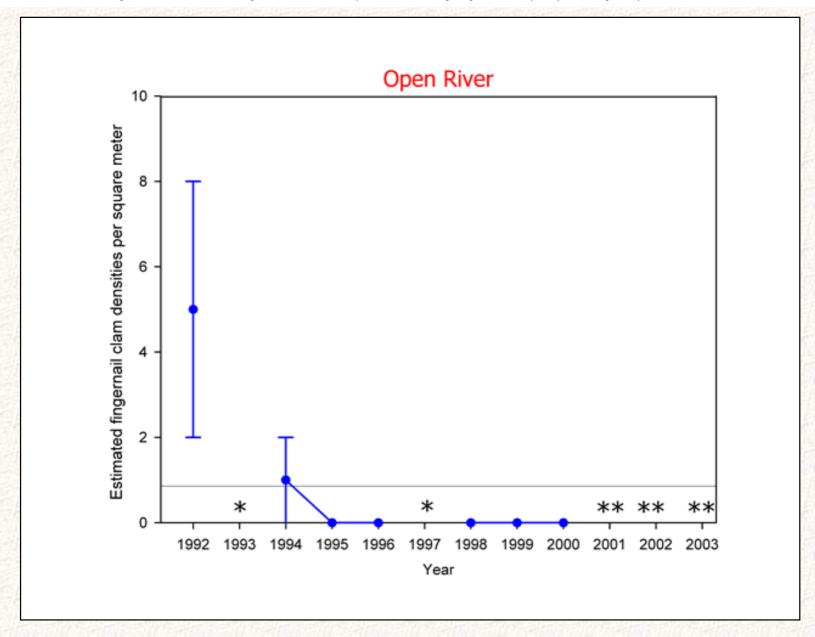
\*\*Sampling not conducted in 2003 because of budget constraints.





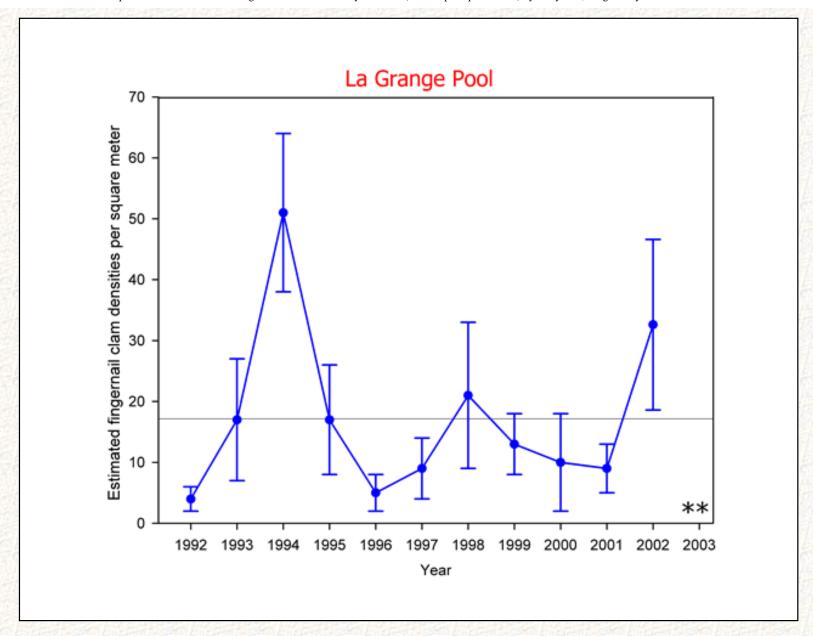


<sup>\*</sup>Sampling not completed because of high water.



<sup>\*</sup>Sampling not completed because of high water.

<sup>\*\*</sup>Sampling discontinued in 2001.



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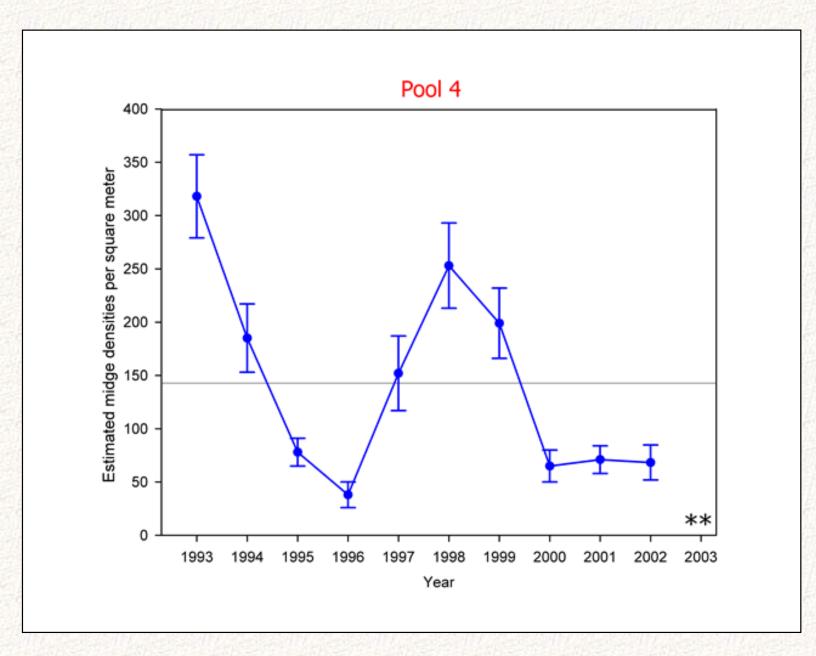
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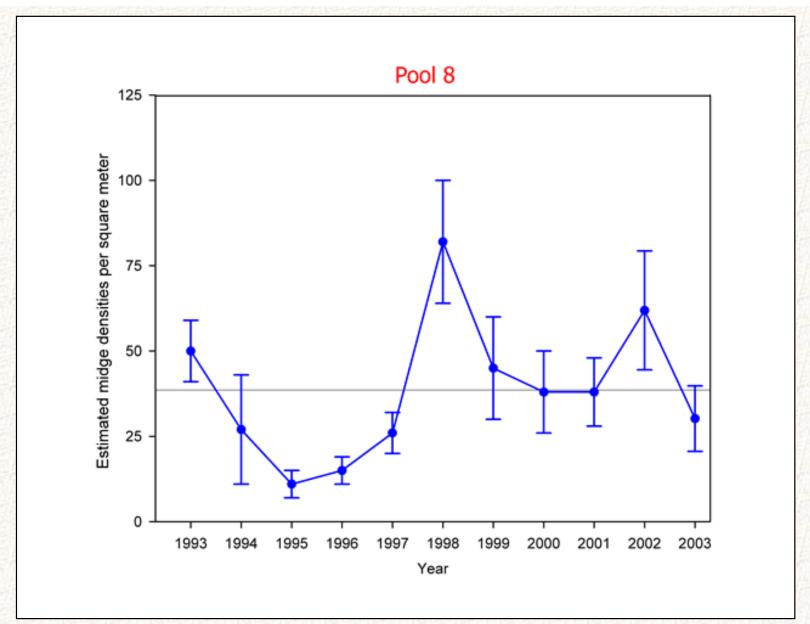


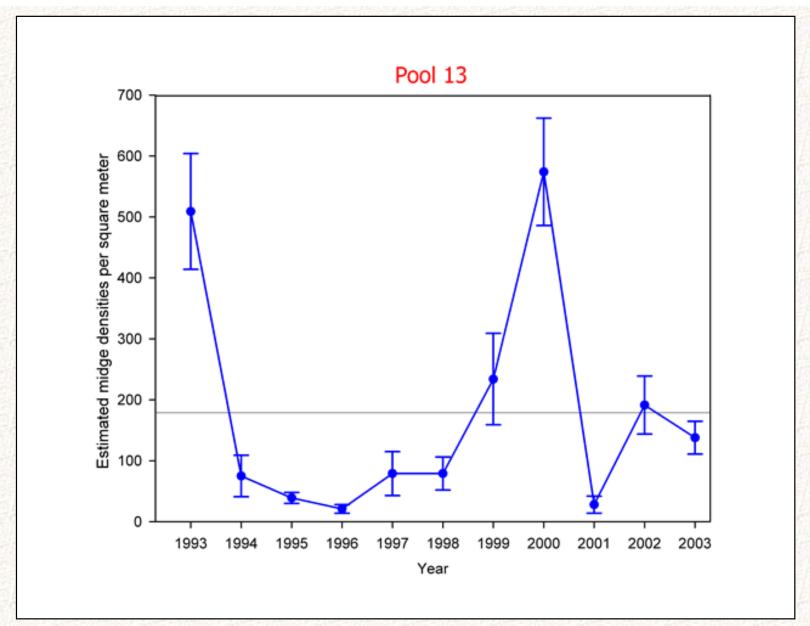
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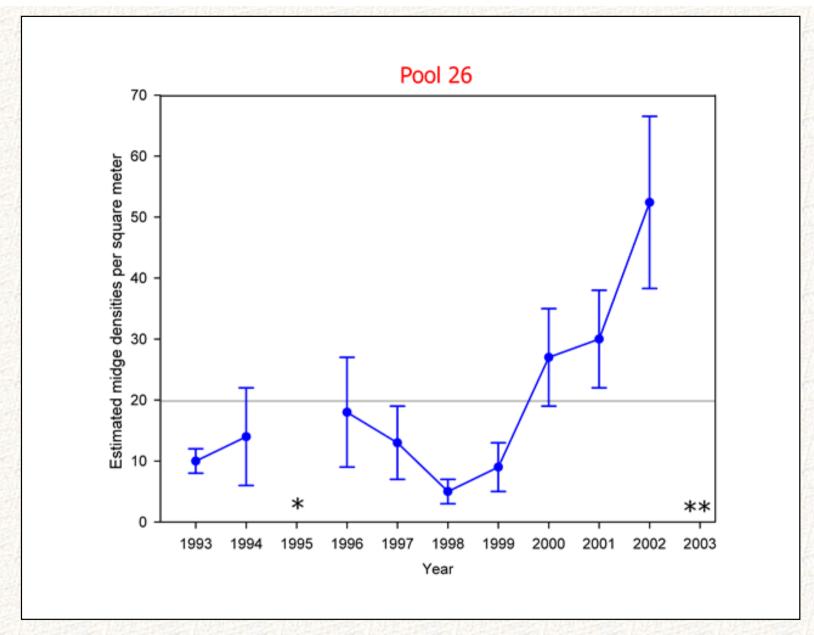
**Figure 4.** Estimated density of midges (number per square meter; ±1 standard error) by study area, weighted by area of strata. Horizontal line indicates grand mean.



<sup>\*\*</sup>Sampling not conducted in 2003 because of budget constraints.

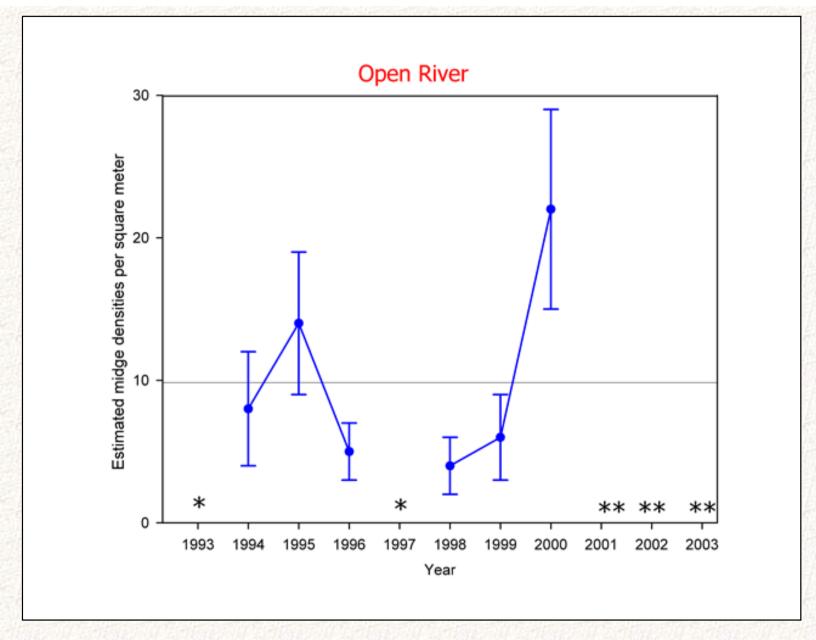






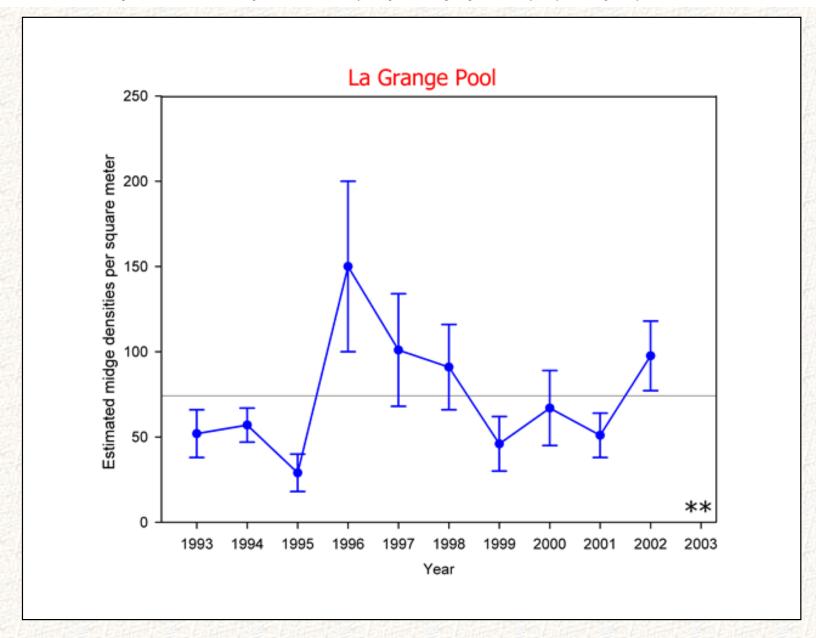
<sup>\*</sup>Sampling not completed because of high water.

<sup>\*\*</sup>Sampling not conducted in 2003 because of budget constraints.



<sup>\*</sup>Sampling not completed because of high water.

<sup>\*\*</sup>Sampling discontinued in 2001.



\*\*Sampling not conducted in 2003 because of budget constraints.

Content manager: Jennie Sauer

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Contact the Upper Midwest Environmental Sciences Center

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